The Mystery Behind PPCPs

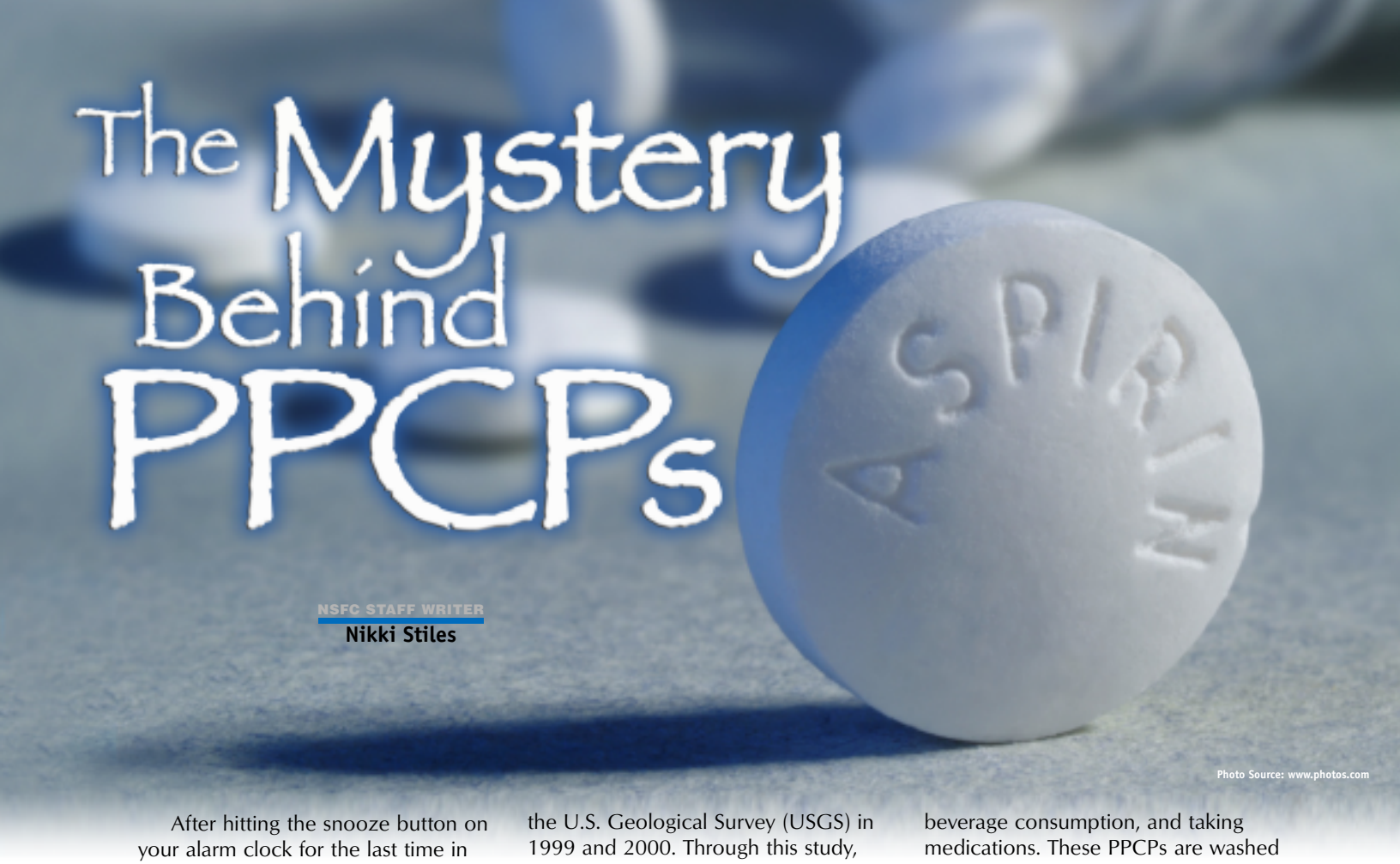

Photo Source: www.photos.com

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After hitting the snooze button on your alarm clock for the last time in the morning, a steaming cup of coffee might sound like just the thing to get you going. But be aware many other uninvited guests may be sharing this "caffeine kick" with you.

Caffeine is just one of many in a long list of compounds known as Pharmaceuticals and Personal Care Pollutants (PPCPs) that many of us consume or use everyday. PPCPs consist of a very broad and diverse collection of thousands of chemical substances, including prescription and over-the-counter therapeutic drugs, nicotine, fragrances, ...etics, sun-...een agents, ...agnostic ...gents, and ...any oth-...s.

Recently, ...CPs have ...rated both ...erest and concern in the U.S. due in part to a study done by the U.S. Geological Survey (USGS) in 1999 and 2000. Through this study, pharmaceuticals were found at low levels, often at concentrations of less than one part per billion, in many of the waterways surveyed. However, there is little information available about the potential effects of this low-level, long-term exposure to combinations of chemicals on human and aquatic life.

"One of the reasons that there's not much known is because the effects that we are worried about are on organisms that were never intended to be exposed to these chemicals," said Christian Daughton, chief of the Environmental Chemistry Branch at the U.S. Environmental Protection Agency (EPA) National Exposure Research Laboratory in Las Vegas, Nevada. "Another issue is the fact that the concentrations at which these chemicals are found in the environment are very low— at one part per billion and lower—and those levels generally have escaped the traditional concerns of toxicologists."

On average americans consume 3.1 cups of coffee per day.
Source: ***www.coffeeresearch.org***

How PPCPs Enter the Environment

PPCPs can enter the environment in a variety of ways. Just consider how many PPCPs the typical person uses or consumes daily through showering, household cleaning, beverage consumption, and taking medications. These PPCPs are washed down the drain, or consumed, excreted, and flushed down the toilet.

Then there are those conscientious consumers, acting on advice given by some poison-control centers, who flush unused medications down the toilet. These PPCPs can enter the environment through failing septic systems, straight pipes, or through discharge from wastewater treatment plants.

Other avenues by which PPCPs enter the environment are through animal manure, as many large feedlots continuously feed their animals sub-therapeutic doses of antibiotics, through field irrigation with reused water, and by application of treated sewage sludge as a soil amendment.

History of PPCPs

Undoubtedly, PPCPs have been in watersheds for as long as soap or aspirin has been used. But the real interest in PPCPs emerged in Europe in the 1980s.

A study in Germany, who has been at the forefront in PPCP research, found PPCPs in treated and untreated sewage effluent, surface water, ground water, and drinking water. Most commonly found were anti-inflammatory and pain-killing drugs, cholesterol-lowering drugs, anti-

convulsants, and hormones from oral contraceptives. Samples from 40 German rivers and streams turned up residues of 31 different PPCPs, according to a report by Thomas Ternes, Ph.D., a chemist at the Institute for Water Research and Water Technology in Wiesbaden.

Daughton, who has developed an extensive EPA Web site on PPCPs, said the water delivery and treatment infrastructure in Europe was the driving force for much of the PPCP research. "They have many more sewage treatment plants whose effluents undergo less dilution by receiving waters than we have in the U.S. It really wasn't until the 1990s that we started paying attention to PPCPs here. It wasn't because we were ignorant; there just wasn't anything driving it," he said.

In fact, Daughton said that EPA scientist Wayne Garrison first documented pharmaceuticals in sewage in the 1970s. Garrison found clofibric acid, which is the active metabolite from a class of lipid-lowering drugs called fibrates. "He reported it among hundreds and hundreds of other chemicals, and that was that," Daughton said. "It wasn't that anyone purposely ignored it— it just didn't capture anyone's attention because we were focused primarily on pesticides and agrochemicals back in the 1970s." Daughton added that the primary reason that clofibric acid caught Garrison's attention in the first place was because its structure is very similar to that of the herbicide, mecoprop.

Most of the research in the U.S. began in the 1990s. As mentioned earlier, most notable was the USGS study conducted in 1999 and 2000. The USGS Toxic Substances Hydrology Program collected and analyzed water samples from 139 streams in 30 states. The sampled watersheds were considered to be susceptible to contamination from various wastewater sources, such as downstream from intense urbanization or livestock pollution. Therefore, the results of this study are not considered representative of all streams.

USGS Study

The USGS found that one or more chemicals were detected in 80 percent of the streams sampled, and 82 of the 95 chemicals being investigated were detected at least once. The most frequently found chemicals were coprostanol (fecal steroid), cholesterol (plant and animal steroid), N-N-diethyltoluamide (insect repellent), caffeine, triclosan (antimicrobial disinfectant), tri (2-chloroethyl) phosphate (fire retardant), and 4-nonylphenol (nonionic detergent metabolite). Generally, these chemicals were found at very low concentrations (in most cases, less than one part per billion).

Although the research in Europe certainly sparked some interest with USGS scientists, it was not the only driving force behind the survey, said Dana Kolpin, USGS research hydrologist. The reason for the survey was more obvious. "It was an area that was really unknown in the U.S. and it was an area that needed to be investigated," he said.

Since the initial survey, USGS has conducted further evaluations of specific drinking water sources. Data from this survey has not yet been published. "We wanted to get an idea of what is in drinking water prior to treatment," Kolpin said. "We started out with this trilogy of broad scale reconnaissance efforts to see what was out there, and now we are transitioning into a more focused research to get a better idea of the sources of these compounds, their fate transport in the environment, and ultimately their effects."

Effects of PPCPs

There are more questions about the possible effects of PPCPs on humans and aquatic life than there are answers. Most of the research to date has only proven that various PPCPs are in the environment. For instance, Chris Metcalfe, environmental scientist at Trent University in Peterborough, Ontario, detected the drugs aspirin, ibuprofen, indomethacin, bezafibrate (a cholesterol regulator), and carbamazepine (an anticonvulsant) in 10 pre- and post-treatment samples taken from wastewater treatment plants in eastern Canada. Metcalfe is just

Photo Source: www.photos.com

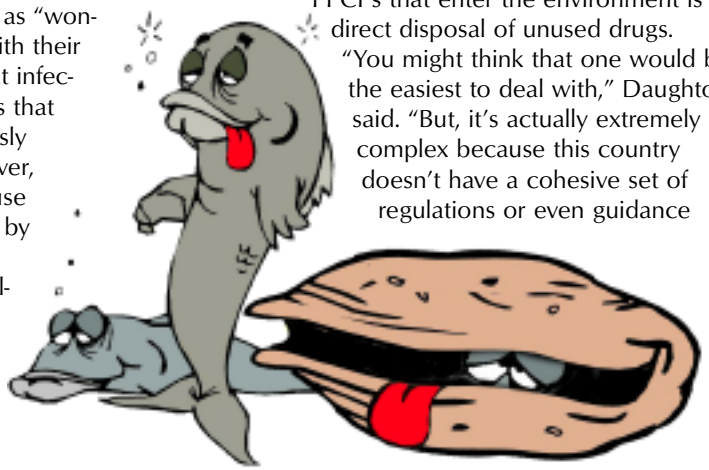
beginning to analyze the effects of cholesterol-lowering drugs, estrogens, and anticonvulsants on fish in the Great Lakes.

In one of the first studies in the U.S. to report the occurrence of drugs in drinking water, environmental engineer Glen Boyd had his students at Tulane University in New Orleans, Louisiana, sample water from the Mississippi River, a local lake, and city tap water. Their preliminary experiment targeted the pain reliever naproxen, the sex hormone estrone, and clofibric acid. All three were detected at varying concentrations in most of the samples.

Although the USGS has not yet explored the effects of PPCPs, Kolpin feels that is an issue that is going to be difficult to access. "We found a broad mix of compounds out there. Rarely, if ever, did we find just one compound present," he said. "Any sort of research of effects has to take a complex mixture into account and that's going to be a complex issue to unravel—to be able to say that this compound or these sets of compounds are causing an observed effect."

Most other research on the effects of PPCPs involves antibiotic and hormone drugs. Research has shown that sex steroids from oral contraceptives and other similar chemicals can feminize male fish and change behaviors of either sex. A three-year study by a research team at Brunel University in the United Kingdom found that many final sewage effluents contain estrogenic hormones believed to originate from women's urine. The research began following the discovery that male fish in the lagoons of a UK wastewater treatment plant had become partly feminized. In Europe, researchers have tied a decline in male sperm count to low levels of birth-control hormones in the environment.

Antibiotics were once viewed as "wonder drugs" with their ability to treat infectious diseases that were previously killers. However, widespread use of antibiotics by both humans and in agriculture has led to antibiotic-resistant bacteria. Traces of antibiotics in watersheds may only magnify this problem.



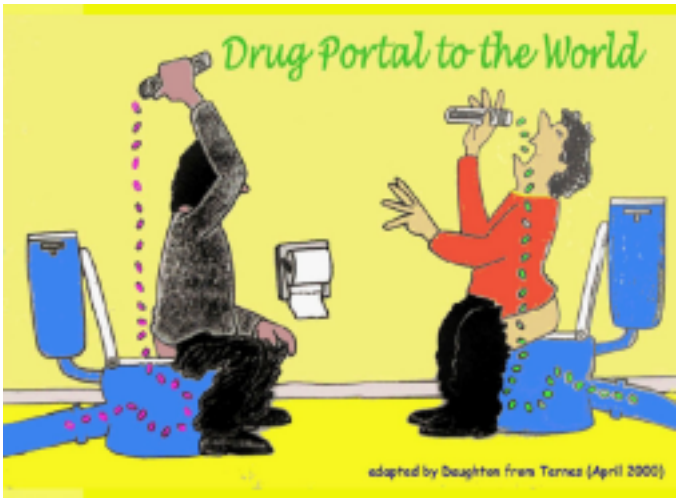
Other Potential Effects

Since much research has already been done on the effects of various hormones and antibiotics, Daughton chose not to explore these areas too deeply in his published papers or Web site. Instead, Daughton focuses on areas that have been virtually unexplored. One area is selective serotonin reuptake inhibitors (SSRIs), which are a major class of widely prescribed antidepressants that include Prozac, Zoloft, Luvox, and Paxil. Limited research shows that SSRIs elicit certain behaviors in shellfish. For example, bivalves' reproductive functions, including spawning, oocyte maturation, and parturition are regulated by serotonin.

Another effect of many drugs, such as the heart medication verapamil, is inhibition of efflux pumps. Efflux pumps are bound to cellular membranes that are responsible for keeping toxic materials from entering the cell, and if they do enter the cell, the efflux pumps work to pump them back out. Daughton hypothesizes that these drugs, as well as other environmental pollutants, can potentially have adverse effects on aquatic life. "These efflux pump systems are extremely important. They are the first line of defense for aquatic organisms to allow them to live in an environment where toxic substances are continually present," he said.

Preventing PPCPs from Entering the Environment

One key to limiting the amount of PPCPs that enter the environment is direct disposal of unused drugs. "You might think that one would be the easiest to deal with," Daughton said. "But, it's actually extremely complex because this country doesn't have a cohesive set of regulations or even guidance



that tells the public what to do with unused drugs. So we need to come up with a cohesive guide for the entire nation on the safest way to dispose of drugs."

Another aspect that could limit the introduction of PPCPs into the environment has to do with their intended use. "There's not much you can do with respect to use because most of these chemicals are considered necessary for human medicine," Daughton said. "There are a wide number of things that can be done with respect to drug design and delivery that can actually lower doses of drugs or make it so that the drug is more environmentally friendly."

PPCPs and Water Reuse

Imagine this scenario: you've just run five miles and desperately need a drink of water. You are given the choice between two glasses of water, one from melted snow that contains all sorts of chemicals at low levels. The second one is virtually chemical free, but contains trace amounts of a single chemical contaminant, and the only reason it is there is because someone put it in his or her mouth and later excreted it. Which of these two waters would you choose?

"People always choose the melted snow," Daughton said. "They don't want to use the other one because it came from someone else's excrement."

This may be the reason behind much of the interest in PPCPs and also the reason that some water reuse projects fail, such as various toilet-to-tap programs, which proposes to reclaim wastewater for drinking, Daughton said.

"I can't tell you whether there are genuine health risks that we need to be concerned about; it just isn't

known," Daughton said. "But what is known is that this is an emotional issue for the public."

Water reuse is common in Hawaii since nearly all of the drinking water supply is obtained from unconfined groundwater aquifiers. Drinking water for the one million residents of Oahu Island in Hawaii is obtained from groundwater. In Oahu, treated wastewater is used to irrigate some agricultural lands and some of the 35 golf courses on the island. Therefore, protecting this groundwater from possible contamination is important.

Roger Babcock, Ph.D., associate professor of civil and environmental engineering at the University of Hawaii, is currently involved with a study on Hawaii's Oahu Island to screen groundwater, wastewater, and reclaimed water for PPCPs. In addition to PPCP detection, the study also determines soil sorption characteristics of selected pharmaceutical compounds, and determines the fate and transport of PPCPs in recycled water during percolation through soil in field test plots.

"What we are trying to do is figure out what the fate of these compounds is when they are discharged into the environment," Babcock said.

Currently, recycled water cannot be used over an aquifer and this was the catalyst for the study, Babcock said. "Recycled water is generally only approved for use in areas where it's not over a drinking water supply, but there is a proposal for fairly large-scale reuse over potable aquifer. This study is aimed at finding out if that's okay," he said.

Results of the study so far indicate pharmaceuticals were found in untreated wastewater and lower levels of PPCPs were found in treated wastewater, but no PPCPs were detected in the groundwater samples taken.

Unanswered Questions

It will probably take many years to solve the mystery of PPCPs. "It seems like the data that people generate lead to more and more questions," Daughton said.

Many of those questions concern the potential effects of PPCPs and many of those are unanswered as well, but one thing is certain—detection of PPCPs does have an emotional impact on all levels of society.

Kolpin speculated that people have a far stronger reaction to the detection of PPCPs verses the detection of pesticides in the environment. "Whenever pesticides were found in the environment, it didn't seem to hit a sensitive nerve with the public. I think they felt that had to do with the farmers and not with them," he said. "But, now when you say you've found ibuprofen or caffeine, it definitely hits a nerve because that's something they use. Now that we know these compounds are out there, the big question is—what are their effects?"

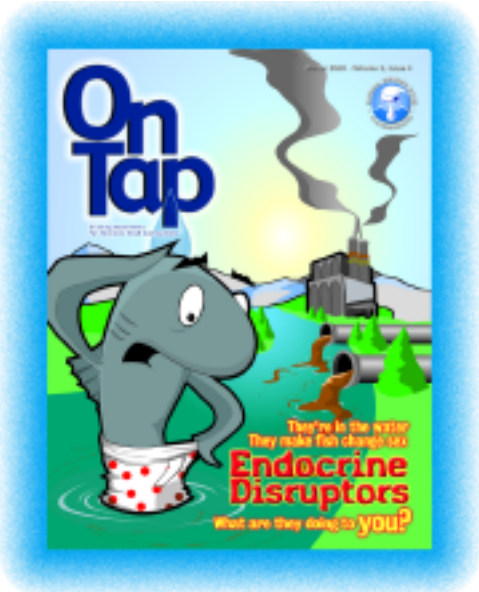
For more information on PPCPs contact Daughton at (702) 798-2207 or **daughton.christian@epa.gov**, Kolpin at (319) 358-3614 or **dwkolpin@usgs.gov**, Babcock at (808) 956-7298 or **rbabcock@hawaii.edu** or visit EPA's Web Site on PPCPs at **www.epa.gov/nerlesd1/chemistry/pharma/index.htm.**

Related Products

For ordering information, see page 47.

Winter 2003 Issue of *On Tap*

Certain chemicals such as pesticides, fertilizers, fuel additives, and detergents, are routinely found in groundwater and surface water. These chemicals can interfere with the balance of normal hormone functions in animals, including humans. The winter 2003 *On Tap* magazine from the National Drinking Water Clearinghouse (NDWC) explores endocrine disruptors and their potential effects on the human body in the cover story, "Endocrine Disruptors: What are they doing to you?"



The "Tech Brief," a regular feature in *On Tap* that describes treatment technologies for drinking water professionals, discusses water hammer. This phenomenon is the momentary increase in pressure that occurs in a water system when there is a sudden change of direction or velocity of the water. These pressure fluctuations can be severe enough to rupture a water main.

The last thing parents want to see in their child's school is a sign in large, block letter saying "Do Not Drink The Water." NDWC's new "How To" series covers manganese greensand treatment units and how a remote, West Virginia school used this treatment method to effectively remove iron and manganese from the drinking water.

Other topics covered in this issue of *On Tap* include:

- grassroots watershed protection in a rural Pennsylvania county;
- water board members, how to train them and keep them;
- security and emergency planning and the efforts required to be prepared for trouble;
- various training solutions for water operators;
- "Tech Trends," offering several news methods for removing arsenic from drinking water; and
- funding alternatives to Rural Utilities Service and state revolving fund loans for small communities.

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